IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, *et al.*	)	
	)	
Plaintiffs,	)	
	)	
v.	)	Case No. 4:05-cv-00329-GKF-PJC
	)	
TYSON FOODS, INC., *et al.*	)	
	)	
Defendants.	)	

DEFENDANTS' RESPONSE IN OPPOSITION TO PLAINTIFFS' MOTIONS IN LIMINE PERTAINING TO ALTERNATE SOURCES OF PHOSPHORUS AND BACTERIA TO THE IRW [Dkt. No. 2436] AND BACTERIAL OR PHOSPHORUS LEVELS IN OTHER WATERSHEDS [Dkt. No. 2411]

EXHIBIT 6
John Connolly Expert Report Excerpts

Quantitative Environmental Analysis, LLC
∂c/∂t

Expert Report

Illinois River Watershed Water Quality and Source Assessment

Prepared for:

Illinois River Watershed Joint Defense Group

Prepared by:

Quantitative Environmental Analysis, LLC

Montvale, NJ

January 30, 2009

UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex. rel. W.A. DREW EDMONDSON, in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA and OKLAHOMA SECRETARY OF THE ENVIRONMENT, J.D. Strong, in his capacity as the TRUSTEE FOR NATURAL RESOURCSE FOR THE STATE OF OKLAHOMA,	)	
Plaintiffs,	)	
	)	**Case No. 05-CV-329-GKF-SAJ**
v.	)	
TYSON FOODS, INC., TYSON POULTRY, INC., TYSON CHICKEN, INC., COBB-VANTRESS, INC., AVIAGEN, INC., CAL-MAINE FOODS, INC., CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTION, LLC, GEORGE'S INC., GEORGE'S FARMS, INC., PETERSON FARMS, INC., SIMMONS FOODS INC., and WILLOW BROOK FOODS, INC.,	)	
Defendants.	)	

EXPERT REPORT OF

John P. Connolly, Ph.D., P.E., B.C.E.E.

Quantitative Environmental Analysis, LLC

January 30, 2009

2.8 THE SIMILARITY OF WATER QUALITY IN LAKE TENKILLER AND OTHER LAKES IN THE REGION INDICATES THAT THE USE OF POULTRY LITTER IN THE ILLINOIS RIVER WATERSHED DOES NOT DEGRADE WATER QUALITY BEYOND WHAT OCCURS BECAUSE OF DEVELOPMENT FOR AGRICULTURE AND URBANIZATION AND THE NATURE OF RUN-OF-RIVER RESERVOIRS.

The Plaintiffs' consultants contend that poultry litter is the principal cause of water quality problems in the Illinois River Watershed. While they acknowledge the presence of other sources of nutrients and bacteria, they conclude that water quality problems would be minimal in the absence of poultry litter application as a fertilizer. If this conclusion is correct, one expects other reservoirs in nearby watersheds that have much less poultry litter application but similar land use to have better water quality. To test this hypothesis, the water quality of other lakes in the state that have watershed characteristics similar to the Lake Tenkiller watershed, but lower poultry populations, were compared to the water quality of Lake Tenkiller.[6]

Lakes Hugo and Sardis, which are in southeastern Oklahoma (Figure 2-17), were found to be the best available comparisons to Lake Tenkiller. All are in the same general physiographic region of the southern Midwest and contain portions of the Arbuckle and Ozark mountain chains, which are characterized, at least in part, by the presence of karst features including caves and conduits to groundwater recharge, flow, and discharge. The land use distributions of the three watersheds are summarized in Table 2-7. The Tenkiller watershed is the most developed and contains the most pasture and hay. All three have a large fraction forested. No records indicated extensive silviculture or industrial activities in any of the watersheds.

[6] Although there is no one "perfect" comparison to Lake Tenkiller that has *all* of the same characteristics, but little or no poultry within the basin, attempts were made to find comparable watersheds that had important characteristics similar to that of the Lake Tenkiller watershed.

Table 2-7. Land use distribution for Lakes Tenkiller, Hugo, and Sardis Watersheds.

Land Cover	Tenkiller	Hugo	Sardis
Open Water	1.5%	2.6%	8.0%
Developed Open Space	5.6%	2.9%	1.5%
Developed, Low Intensity	2.1%	0.3%	0.1%
Developed, Medium Intensity	0.7%	0.1%	0.0%
Developed, High Intensity	0.3%	0.0%	0.0%
Barren Land	0.1%	0.1%	0.0%
Deciduous Forest	41.5%	33.7%	44.8%
Evergreen Forest	1.2%	23.3%	12.8%
Mixed Forest	0.5%	7.4%	9.0%
Shrub/Scrub	0.5%	1.6%	1.6%
Grassland/Herbaceous	3.4%	8.6%	5.6%
Pasture/Hay	42.0%	18.0%	15.4%
Cultivated Crops	0.1%	0.2%	0.0%
Woody Wetlands	0.6%	1.2%	1.1%
Emergent Herbaceous Wetlands	0.0%	0.1%	0.0%

Land cover information from 2001 Multi-Resolution Land Cover dataset.

An important characteristic pertinent to the comparison is the ratio of the size of the watershed to the size of the reservoir. This watershed to water surface area ratio is a measure of the area of land contributing runoff per unit area of reservoir. A higher value means more potential for water quality issues because relatively more land is contributing nutrients and bacteria to the lake. Given the importance of the watershed to water surface area ratio, comparisons to Lake Tenkiller need to be made in light of differences in these ratios.[7] The watershed to lake area ratios of Lakes Tenkiller, Hugo, and Sardis are 82.3, 81.4, and 12.3, respectively (Table 2-8). These ratios indicate that Tenkiller and Hugo undergo similar areal loading, while Sardis experiences significantly less.

[7] It should be noted that Drs. Cooke and Welch identify the watershed to water surface area ratio as an important differentiation between lakes and run-of-the-river reservoirs on page 9 (last paragraph) of their report. However, they ignore this characteristic when comparing Broken Bow to Lake Tenkiller. Broken Bow has a watershed to water surface area ratio of 37, while Lake Tenkiller's is 82. See Horne (2009) and Sullivan (2009) for further discussion concerning the inappropriateness of using Broken Bow as a comparative watershed to Lake Tenkiller.

Table 2-8. Comparison of various watershed characteristics among Lakes Tenkiller, Hugo, and Sardis.

Lake	Storage Conservation Control Pool (acre-ft)	Watershed Area (acre)	Water Surface Area (acre)	Watershed/ Water Surface Area Ratio	Average Depth (ft)
Lake Tenkiller	654,100	1,052,800	12,800	82.3	51.1
Lake Hugo	166,954	1,093,760	13,440	81.4	12.4
Lake Sardis	274,333	167,040	13,610	12.3	20.2

Hugo and Sardis have fewer poultry counts per unit area than Tenkiller (Table 2-9). The Tenkiller watershed contains approximately 213 animal units of poultry per square mile. The Hugo and Sardis watersheds contain seven and less than one animal units per square mile, respectively. The cattle populations in the Tenkiller, Hugo, and Sardis watersheds are 42, 28, and 25 animal units per square mile and the swine populations are 7, 2, and 6 animal units per square mile, respectively. The Tenkiller watershed contains the greatest density of people; 163 per square mile compared to 12 and 8 in Hugo and Sardis, respectively.

Table 2-9. Population counts for the Tenkiller, Hugo, and Sardis watersheds.

Lake	Active Poultry Houses per sq mi	2002 Cattle Animal Units per sq mi[1]	2002 Swine Animal Units per sq mi[1]	2005 Human Population per sq mi
Lake Tenkiller	1.2 (1.1)[2]	106	18	163
Lake Hugo	0.02	28	2	12
Lake Sardis	<0.01	25	6	8

Notes:
1. Poultry, cattle, and swine animal units acquired through personal communication with Raleigh Jobes.
2. Number of active poultry houses per Plaintiffs' consultant J. Berton Fisher. Number of active poultry houses per defendants' contract growers in parentheses.

A review of USEPA Water Discharge Permits revealed no significant point-source dischargers in either the Hugo or Sardis watersheds. Point-source dischargers are direct contributors to the nutrient loads in a watershed. The absence of significant discharges not only eliminates anomalous nutrient sources in the comparative watersheds, but further supports the assertion that there are comparable or less human populations and industry in the Hugo and Sardis watersheds as compared to the Illinois River Watershed.

Run-of-the-river reservoirs typically have lacustrine, transitional, and riverine zones. Generally, these different zones have differing water quality. Hugo and Sardis are somewhat unique in that the transition from river to lake occurs over a short distance and these lakes lack the type of riverine zone seen in Tenkiller (Figures 2-18a through 2-18c). When comparing the water quality among these three lakes, it is critically important that comparisons are made for like sections.

A reservoir's residence time can influence water quality. If the residence time is short (i.e., less than about two months; Baker and Dycus 2006), the loss of phytoplankton with the water flowing out of the reservoir can limit the maximum phytoplankton concentration in the reservoir. Table 2-10 shows an estimate of the residence times of the three reservoirs. Because Lake Hugo's residence time is low enough to potentially impact maximum phytoplankton concentrations (i.e., maximum chlorophyll-a concentrations), it needs to be considered when comparing Lake Hugo to the other two reservoirs.

Table 2-10. Estimate of residence times for Lakes Tenkiller, Hugo, and Sardis.

Reservoir	Age (yrs)	Volume[a] (ac-ft)	Average Depth (ft)	Approx. Long-Term Average Inflow (cfs)	Period of Record	Estimated Residence Time (months)[b]			
						Whole Lake	Riverine	Transitional	Lacustrine
Hugo	33	157,700	11.9	2,100	1995-2007	1.3	0.1	0.4	0.7
Sardis	27	274,330	20.2	325	1995-2007	14.2	-	2.5	11.7
Tenkiller	56	654,100	50.7	1,245	1997-2007	8.8	0.3	1.3	7.3

[a] *At normal pool elevation.*
[b] *At long-term average inflows.*
Long term average inflow for Hugo, Sardis, and Broken Bow determined from United States Army Corps of Engineers (USACE) charts, for Tenkiller, used average United State Geological Survey (USGS) flows for Baron Fork, Caney Creek, and Illinois River at Talequah.

Water quality was compared in two ways. The phytoplankton concentrations, measured as chlorophyll-a, total phosphorus, and SRP concentrations in the upstream sections provide some sense to the potential impact of point and non-point sources of phosphorus in the watershed. The chlorophyll-a, total phosphorus, and SRP concentrations, dissolved oxygen profiles in the lacustrine sections, and chlorophyll-a Trophic State Index (TSI) values provide evidence of the water quality impacts resulting from the watershed loads.

Figure 2-19 and Table 2-11 show the average surface concentrations of chlorophyll-a, total phosphorus, and SRP during the summer season (May through September) in the transitional section of each lake. The chlorophyll-a concentrations in the transitional sections of Lakes Hugo, Sardis, and Tenkiller during 2003 and 2005, where contemporaneous data are available, were similar in magnitude. These transitional section concentrations in 2003 and 2005 were 9.2, 7.0, and 8.0 μg/L and 11.0, 7.4, and 15.6 μg/L, respectively. Similar transitional section chlorophyll-a concentrations indicate that despite the smaller poultry populations in the Hugo and Sardis watersheds, a shorter residence time in Lake Hugo, and the lower lake to watershed ratio of Lake Sardis, the three lakes exhibit similar potential impact from their respective watersheds. This conclusion is further supported by similar total phosphorus and SRP concentrations in the transitional sections of the three lakes from 2003 and 2005. The average transitional section total phosphorus concentrations in Lakes Hugo, Sardis, and Tenkiller in 2003 and 2005 were 0.08, 0.02, and 0.17 mg/L and 0.08, 0.03, and 0.02 mg/L, respectively. The average transitional section SRP concentrations in 2003 and 2005 were 0.03, 0.01, and 0.09 mg/L and 0.03, 0.01, and <0.01, respectively.

Table 2-11. Summer surface average and chlorophyll-a, total phosphorus, and SRP concentrations in the transitional section of Lakes Hugo, Sardis, and Tenkiller from 2003 and 2005.

Parameter	Year	Lake	Number of Observations	Average	Minimum	Maximum	Units
Chlorophyll-a	2003	Hugo	5	9.2	4.9	13.0	mg/L
		Sardis	2	7.0	6.7	7.3	mg/L
		Tenkiller	13	8.0	2.9	33.2	mg/L
	2005	Hugo	3	11.0	8.0	13.0	mg/L
		Sardis	2	7.4	6.4	8.4	mg/L
		Tenkiller	25	16.2	8	32.3	mg/L
Total Phosphorus	2003	Hugo	6	0.077	0.068	0.091	mg/L
		Sardis	4	0.017	0.010	0.023	mg/L
		Tenkiller	5	0.171	0.025	0.310	mg/L
	2005	Hugo	6	0.081	0.072	0.093	mg/L
		Sardis	2	0.028	0.027	0.028	mg/L
		Tenkiller	15	0.023	0.003	0.033	mg/L
Soluble Reactive Phosphorus	2003	Hugo	6	0.031	0.016	0.043	mg/L
		Sardis	4	0.009	0.007	0.011	mg/L
		Tenkiller	6	0.090	0.010	0.190	mg/L
	2005	Hugo	6	0.033	0.024	0.043	mg/L
		Sardis	2	0.011	0.010	0.011	mg/L
		Tenkiller	15	0.002	0.001	0.005	mg/L

An analysis of the average surface concentrations of chlorophyll-a, total phosphorus, and SRP during the summer season (May through September) was also performed for the lacustrine section of the three lakes (Figure 2-20 and Table 2-12). Generally, the total phosphorus and SRP concentrations are lower in the lacustrine section of each lake as compared to upstream sections due to the settling of nutrients to the lake floor and phytoplankton utilization of the nutrients upstream of the lacustrine section. Chlorophyll-a concentrations are generally lower in the lacustrine section because nutrient concentrations are lower.

Table 2-12. Summer surface average total phosphorus, SRP, and chlorophyll-a concentrations in the lacustrine section of Lakes Hugo, Sardis, and Tenkiller from 2003 and 2005.

Parameter	Year	Lake	Number of Observations	Average	Minimum	Maximum	Units
Chlorophyll-a	2003	Hugo	4	5.5	2.6	10.6	µg/L
		Sardis	3	5.8	4.5	6.5	µg/L
		Tenkiller	26	4.8	1.2	9.9	µg/L
	2005	Hugo	2	9.0	6.0	12.0	µg/L
		Sardis	2	7.3	6.6	8.1	µg/L
		Tenkiller	47	11.1	4.0	36.8	µg/L
Total Phosphorus	2003	Hugo	4	0.060	0.040	0.081	mg/L
		Sardis	6	0.017	0.010	0.037	mg/L
		Tenkiller	13	0.146	0.011	0.420	mg/L
	2005	Hugo	4	0.068	0.051	0.090	mg/L
		Sardis	4	0.022	0.005	0.028	mg/L
		Tenkiller	24	0.013	0.008	0.027	mg/L
Soluble Reactive Phosphorus	2003	Hugo	4	0.027	0.016	0.038	mg/L
		Sardis	6	0.008	0.006	0.010	mg/L
		Tenkiller	17	0.073	0.005	0.170	mg/L
	2005	Hugo	4	0.031	0.019	0.046	mg/L
		Sardis	4	0.009	0.005	0.010	mg/L
		Tenkiller	22	0.003	0.001	0.013	mg/L

Identical comparisons and trends were apparent in the lacustrine sections as in the transitional sections of the three lakes. The 2003 and 2005 average summer surface chlorophyll-a and nutrient concentrations in the lacustrine sections of the three lakes were similar and lacustrine section nutrient concentrations in Lake Tenkiller decreased from 2003 to 2004. Lakes Hugo, Sardis, and Tenkiller average 2003 and 2005 summer surface chlorophyll-a lacustrine section concentrations were 5.5, 5.8, and 4.8 µg/L and 9.0, 7.3, and 11.1 µg/L, respectively. Lacustrine section total phosphorus concentrations were 0.06, 0.02, and 0.15 mg/L and 0.07, 0.02, and 0.01 mg/L, and SRP concentrations were 0.03, 0.01, and 0.07 mg/L and 0.03, 0.01, and <0.01 mg/L, respectively. These results further indicate similar water quality in the three lakes despite the lower poultry populations in the Hugo and Sardis watersheds and existing conditions in Lakes Hugo and Sardis that should improve water quality as compared to Lake Tenkiller (shorter residence time and lower watershed to lake ratio, respectively).

Figure 2-21 shows dissolved oxygen profiles in the lacustrine sections of Lakes Tenkiller, Hugo, and Sardis and the Plaintiff's comparison reservoir, Lake Broken Bow. The profiles were all taken during July and August. The four lakes have relatively high dissolved oxygen concentrations in the top 5 m and then trend toward zero dissolved oxygen near 10 m depth. Data are not available in Lake Sardis below 8 m and Lake Hugo has a relative shallow average depth, but the trend of the data appears similar for all four reservoirs. These dissolved oxygen profiles indicate that all of the reservoirs experience the common phenomena of dissolved oxygen depletion, even those whose watersheds have little poultry population. In fact, Sardis and Broken Bow, which have significantly lower watershed to water surface area ratios than the Tenkiller and Hugo, and thus potentially lower nutrient impacts, still show oxygen depletion in the bottom waters. In fact, most man-made run-of-river reservoirs will experience some level of dissolved oxygen depletion in the bottom waters, unless some other mechanism (such as wind mixing in shallow reservoirs) hinders dissolved oxygen depletion. In general, altering a natural system via dam construction inevitably results in water quality issues. Consequently, thermal stratification and resulting low dissolved oxygen levels in deeper waters is normal for run of the river reservoirs (Thornton et al. 1990)

Finally, chlorophyll-a TSI values were calculated for each section and the entire lake of Lakes Tenkiller, Hugo, and Sardis for the summer of 2005 (Figure 2-22). Trophic State Index provides a "rule-of-thumb" measure of the tropic status of the reservoir. The Oklahoma Water Resources Board (OWRB) uses chlorophyll-a TSI to assess what lakes in Oklahoma are eutrophic (or hypereutrophic) and potentially need to be managed to control algae. The TSI values calculated from a compilation of all available data are similar to the values found in Oklahoma's Beneficial Use Monitoring Program (BUMP) – Lakes Sampling, 2006-2007 Draft Report (OWRB 2007; eutrophic or borderline eutrophic). These results further support the existence of similar water quality issues in the three lakes, regardless of their poultry populations or conditions in Lakes Hugo and Sardis that should mitigate water quality impacts (shorter residence time and lower watershed to lake ratio, respectively).

Water quality issues in watersheds with low poultry populations relative to the Illinois River Watershed supports the conclusion that poultry litter is not the primary reason for water quality issues that exist in Lake Tenkiller. There are other factors affecting water quality in Lakes Tenkiller, Hugo, and Sardis. These include:

1. urban and rural development which increases impervious cover, lawn and golf course fertilization, wastewater treatment plant (WWTP) discharges, and the number of septic systems in the watershed (Nelson et al. 2002; Soerens 2003; Sonoda 2007);
2. deforestation and related erosion (Perry et al. 1999; Zheng 2005; Grip 2008; Grip 2009);
3. row crop synthetic fertilizers and related erosion (Sharpley and Smith 1990; Sharpley et al. 2003; Wortmann 2005);
4. other livestock operations such as cattle and swine (USDA 2003; Shaffer 2005; Wortmann 2005; Beede 2007); and
5. inputs from humans during recreational use (see Jarman 2008 for discussion).

Finally, and most importantly, altering a natural system via dam construction inevitably results in water quality issues. These water quality issues arise due to restricting sediment flux out of a watershed and decreasing the potential and kinetic energy of the system, which increases residence time in the water body and thus promotes growth of phytoplankton.[8]

2.9 WASTEWATER TREATMENT PLANTS APPEAR TO BE THE MOST IMPORTANT SOURCE OF BIOAVAILABLE PHOSPHORUS TO THE SYSTEM

Many wastewater treatment plants in the Arkansas and Oklahoma portions of the Illinois River Watershed installed significant upgrades within the past decade, the majority of which were in place by 2004 (Jarman 2008). Improvements have been seen in water quality

[8] Lakes Hugo and Sardis watersheds do not have significantly more urbanization, human population, or other animal populations compared to Lake Tenkiller. Consequently, the water quality issues observed in Lakes Hugo and Sardis even with the lower poultry populations can not be attributed to just urbanization, deforestation, or other animal populations.

SECTION 6
THE WATER QUALITY IN THE ILLINOIS RIVER WATERSHED IS COMPARABLE TO OTHER WATERS IN OKLAHOMA

6.1 SUMMARY OF DETAILED FINDINGS

- The water quality of Lake Tenkiller is comparable to other systems within Oklahoma.
- Water quality of the rivers, specifically, Illinois River, is comparable to other rivers within Oklahoma.

6.2 THE WATER QUALITY OF LAKE TENKILLER IS COMPARABLE TO OTHER SYSTEMS WITHIN OKLAHOMA

Each year, the OWRB compiles a report detailing the state of water quality within Oklahoma's lakes and rivers (i.e., the BUMP report). In addition, every other year, Oklahoma is required by the USEPA to assess all waters of the state and determine which are not meeting their designated uses (e.g., fishable, swimmable, drinkable, etc.). Those not meeting their uses are called "impaired" and are required to undergo additional monitoring and analysis to determine what needs to be done to eliminate the impairment. These two water quality assessment exercises allow us to compare Lake Tenkiller's water quality to other reservoirs and lakes in the state.

The monitoring program for the BUMP tends to focus on water bodies that have potential water quality concerns and therefore, can result in a somewhat "biased" view of the water quality in the state. However, comparisons can still be made, while keeping this sampling protocol in mind. A review of the 2007 BUMP report provides a comparison of Lake Tenkiller's TSI with other sampled reservoirs and lakes (OWRB 2007). As discussed in Section 2, a TSI provides an estimate of the level of eutrophication in a lake, with higher numbers indicating greater eutrophication, in general. Figure 6-1 shows the chlorophyll-a TSIs for all lakes and reservoirs sampled from 2004 to 2007. These TSIs are representative of the summer (i.e., the BUMP sampling period) and include data from the entire water body (i.e., the BUMP assessment does not break out a reservoir into riverine, transitional, or lacustrine zones). Figure 6-1 indicates that 61% of the lakes sampled from 2004 to 2007 were classified as eutrophic or hypereutrophic, according to its chlorophyll-a TSI. Lake Tenkiller was one of those reservoirs, but 14% of the lakes were at a higher tropic level (hypereutrophic) than Lake Tenkiller. The probability distribution of the chlorophyll-a TSIs calculated from 2004 to 2007 shows that Lake Tenkiller lies at about the 58th percentile, meaning that about 42 percent of the lake's sampled had TSIs higher than Lake Tenkiller (Figure 6-2, bottom panel). In addition, the spatial pattern of chlorophyll-a TSI determined from Plaintiff's data collected in summer 2006 indicates that Lake Tenkiller's lacustrine area (represented by LK-01 and LK-02) is mesotrophic, which is typical for a run-of-the-river reservoir (see Horne 2009 for further discussion).

Inspection of total phosphorus collected during the BUMP effort shows a story similar to chlorophyll-a. Figure 6-3 displays the total phosphorus concentrations of the different reservoirs for summers of 2005 and 2007. Forty-percent of the lakes sampled during these two summers had phosphorus in the same range as Lake Tenkiller, while 37% had concentrations in a range higher than Lake Tenkiller.

Table 6-1 shows the biennial assessment of state waters from the preliminary 2008 report that was submitted to USEPA (ODEQ 2008). Only the constituents for which Lake Tenkiller is listed as "impaired" are shown in the table. Close to 11% of the assessed lakes are considered impaired based on chlorophyll-a and close to 63% of Oklahoma's assessed lakes are listed for low dissolved oxygen. Lake Tenkiller's chlorophyll-a impairment accounts for just 1.4% of the total assessed lakes and about 2% of the all the assessed lakes in relation to dissolved oxygen impairment. More importantly, Table 6-1 shows that there are many other lakes within Oklahoma that have water quality impairments. The assessment for total phosphorus is not yet performed on a state-wide basis and therefore, it is difficult to draw any conclusions regarding the impairment listing of Lake Tenkiller for total phosphorus.

Table 6-1. Percentage of lakes in Oklahoma with similar impairments as Lake Tenkiller.

Impairment	Size of Lake Tenkiller Impaired (acres)	Waterbodies in Illinois River Watershed		Lakes in Oklahoma		
		Total Lake Size Impaired (acres)	Total Lake Acres Assessed within Watershed	Total Acres of Lakes Impaired in Oklahoma (acres)	Total Lake Acres Assessed, with Sufficient Data or Information [2]	% of Assessed Lake Acres Impaired
Chlorophyll-*a*	8,440	8,440	14,034	66,222	622,176	10.6%
Dissolved Oxygen	13,470	13,470	14,034	389,498	622,176	62.6%
Total Phosphorus	8,440	8,440	n/a [3]	15,877	n/a [3]	---

Notes:

1. *Source: Oklahoma Department of Environmental Quality, 2008. The State of Oklahoma 2008 Water Quality Assessment Integrated Report.*
2. *Excludes 303(d) List Category 3 stream miles. Integrated report does not list acres assessed by impairment, only total acres assessed for any one constituent..*
   Category 3 - Insufficient or no data and information to determine if any designated use is attained.
3. *n/a = not available; lakes assessed for phosphorus unknown.*

The above information, combined with the analysis performed in Section 2.8 (i.e., the analysis of water quality in Lakes Hugo and Sardis watersheds) indicates that Lake Tenkiller's water quality is comparable to other reservoirs within the state. The water quality of Lake Tenkiller is not unusual and does not indicate significant issues. In fact, for a large portion of the lake (the lacustrine zone), the water quality is well within acceptable levels for chlorophyll-a and total phosphorus.

6.3 THE WATER QUALITY OF THE ILLINOIS RIVER IS COMPARABLE TO OTHER SYSTEMS WITHIN OKLAHOMA

6.3.1 Dissolved Oxygen Levels in the Illinois River Watershed Are Comparable or Better Than Many Other River Systems within Oklahoma

According to the State of Oklahoma's 303(d) list, low dissolved oxygen is a common problem in the state. About 2,500 miles of rivers and streams are listed as impaired for dissolved oxygen (Table 6-2). This represents about 20 percent of the total river miles assessed by the state. Within the Illinois River Watershed, the state listed only 1.6 miles as impaired due to dissolved oxygen and no part of the main stem of the Illinois River.

Table 6-2. Percentage of rivers/streams/creeks in Oklahoma with similar impairments as those in the Illinois River and its watershed.

Impairment [2]	Main Stem of Illinois River	All Waterbodies in Illinois River Watershed			Rivers/Streams/Creeks in Oklahoma		
	Total Stream Miles Impaired	Total Stream Miles Impaired	Total River Miles Assessed [3]	% of Assessed Stream Miles Impaired	Total Stream Miles Impaired	Total River Miles Assessed, with Sufficient Data or Information [4]	% of Assessed Stream Miles Impaired
Dissolved Oxygen	0	1.6	551.5	0.3%	2,547	12,511	20.4%
Enterococcus	12.9	112.2	551.5	20.3%	6,977	12,511	55.8%
Escherichia Coli	31.7	37.9	551.5	6.9%	3,495	12,511	27.9%
Fecal Coliform	31.7	31.7	551.5	5.7%	3,094	12,511	24.7%
Lead	31.7	31.7	551.5	5.7%	1,437	12,511	11.5%
Total Phosphorus	60.2	92.8	92.8	100.0%	160	185 [5]	86.5%
Turbidity	5.2	5.2	551.5	0.9%	4,012	12,511	32.1%

Notes:
1. *Source: Oklahoma Department of Environmental Quality, 2008. The State of Oklahoma 2008 Water Quality Assessment Integrated Report.*
2. *Only impairments listed for the main stem of the Illinois River are listed.*
3. *Appendix B of integrated report does not list miles by impairment. Assumed that miles reported pertain to all constituents except phosphorus.*
4. *Excludes Category 3 stream miles. Integrated report does not list miles assessed by impairment, only total miles assessed.*
   Category 3 - Insufficient or no data and information to determine if any designated use is attained.
5. *Total river miles estimated from 'Scenic River'-designated water bodies in Oklahoma.*
   Estimated based on Scenic River area descriptions in Oklahoma Statute.
   Length of Big Lee's Creek not limited by the 420-foot MSL elevation due to limited available information.

Using data collected between 2004 and 2007, I looked at dissolved oxygen conditions throughout the state.[26] Many locations failed to meet the dissolved oxygen standards[27] and a number of locations had problems in multiple years (Figure 6-4). In contrast, within the Illinois River Watershed only one small section of river did not meet standards, and that was only during one of the four years considered.

[26] Only locations with at least eight records in at least two years were considered. In addition, to ensure year-round oxygen status, only locations with at least one dissolved oxygen records in at least three quarters (three-month periods) were considered.

[27] The Oklahoma dissolved oxygen regulations are written such that if 10% of readings at a particular location are found to be below a certain criteria, that location is considered impaired due to low dissolved oxygen. In the summer in the much of the Illinois River Watershed, that the criteria are 5.0 mg/L., and 6.0 mg/L for the rest of the year. In some other areas of the Oklahoma the summer and rest-of-the-year the criteria are 4.0 mg/L and 5.0 mg/L, respectively.

This four-year assessment, combined with lack of Illinois River Watershed waters on the state 303(d) list, demonstrates that dissolved oxygen is not a particular concern in the Illinois River Watershed.

6.3.2 Bacteria Indicator Levels in the Illinois River Watershed Are Comparable to Other Systems within Oklahoma

Bacteria groups that may be monitored as indicators of risk for water-transmitted illness from fecal contamination to humans are reviewed in Section 5.2 of this report. River locations throughout the state of Oklahoma are routinely tested for all three standard indicator bacteria groups. Here, results throughout Oklahoma were compared to determine the relative degree of indicator bacteria contamination within the Illinois River Watershed to statewide levels of contamination.

6.3.2.1 Data sources and analysis methods for Oklahoma bacterial indicator comparison

Oklahoma indicator bacteria data were compiled from the following databases: the USGS, the OWRB, the Oklahoma Conservation Commission, USEPA STORET, and the Oklahoma Attorney General. Only data results in units of CFU/100 ml or MPN/100 ml were considered, and values below the detection limit were set equal to the detection limit for analysis. Sample IDs for each USGS/Oklahoma sampling location were standardized so that all available data could be combined for each location (OK station ID formats varied among data sources and the USGS and OK use different ID series for the same stations).

According to USEPA guidance, to indicate the typical impairment level of a water body, one uses the geometric mean of bacteria counts in samples collected over the duration of the swimming season (USEPA 1986, 2004). This is the period during which full-body immersion resulting in oral disease transmission is most likely to occur. Therefore, in this analysis, only samples collected from May through September, the likely extent of the swimming season in Oklahoma and the usual sampling period for the USGS and Oklahoma, were included. Samples in each swimming season were combined to calculate the seasonal geometric mean for that year and location. Duplicates and other cases of multiple samples per day were averaged to get one value per date prior to geometric mean analysis.

The geometric means calculated here are not directly comparable to water quality standards because a lower cutoff for frequency of sampling was used. The point of this analysis is to compare statewide results to each other, not to a standard. (USEPA guidance indicates bacteria samples should be collected at a frequency of five per 30 days for public swimming locations, but the Oklahoma data were typically collected less frequently, usually 1-2 times per month). Geometric means were calculated only in cases where there were at least five sampling dates per season for that location (a frequency of at least one per month).

Results were analyzed for the 2003, 2004, and 2006 swimming seasons. There was insufficient sampling in 2005, 2007, and 2008 to conduct statewide comparisons for those years. Earlier years were not considered.

6.3.2.2 Results of Oklahoma bacterial indicator comparison

Enterococci geometric means for May through September throughout Oklahoma are shown for 2003, 2004, and 2006 in Figures 6-5a, 6-5b, and 6-5c respectively. The Illinois River Watershed is shaded grey in all figures, and results are color coded with respect to how the geometric mean compares to the USEPA water quality criteria threshold (WQT) of 33/100 ml (CFU/100 ml or MPN/100 ml) for enterococci. In 2003, no site in Oklahoma had a seasonal value for enterococci below the WQT, and values in excess of 5 times (5x) the WQT occurred frequently throughout the state. However, the Illinois River Watershed contained a lower concentration of enterococci (some values in the 1-2x WQT range) than was typical for the state. In 2004, enterococci values were somewhat lower than 2003, but the majority of sampled locations both within and outside of the Illinois River Watershed were still in excess of 2x the WQT. In 2006, while there were far more enterococci results < 2x the WQT, some values > 5x the WQT still occurred, however values did not exceed 5x the WQT in the Illinois River Watershed, and did not exceed 1x the WQT in Lake Tenkiller.

Escherichia coli geometric means for May through September in Oklahoma are shown for 2003, 2004, and 2006 in Figures 6-5d, 6-5e, and 6-5f respectively. Results are color coded with respect to the 126/100ml WQT for *E. coli*. In contrast to enterococci, *E. coli* values > 1x the WQT were relatively rare in all three years. More values > 1x the WQT occurred in 2003 and 2006, than in 2004, including two within the Illinois River Watershed in 2003. There were no *E. coli* geometric mean values > 1x the WQT in the Illinois River Watershed in 2004 or 2006.

Fecal coliform geometric means for May through September in Oklahoma are shown for 2003, 2004, and 2006 in Figures 6-5g, 6-5h, and 6-5i respectively, with results color coded with respect to the 200/100ml WQT for fecal coliform. In keeping with enterococci and *E. coli* results, geometric mean values for fecal coliform within the Illinois River Watershed were similar to, or less than, the rest of Oklahoma.

In summary, this data analysis found the magnitude of seasonal indicator bacteria geometric mean values in the Illinois River Watershed were typical of values throughout the entire state of Oklahoma. Thus, there is no evidence that local poultry litter application contributes to exceptional levels of indicator bacteria, and by association risk of waterborne illness, within the Illinois River Watershed.